

Abstract

The phoneme monitoring task used by Bigand, Tillmann, Poulin, D'Adamo and Madurell (2001) is a musical priming paradigm that demonstrates that both musicians and non-musicians have gained implicit understanding of prevalent harmonic structures. Little research has focused on implicit music learning in musicians and non-musicians. This current study aimed to investigate whether the phoneme monitoring task would identify any implicit memory differences between musicians and non-musicians. It focuses on both implicit knowledge of musical structure and implicit memory for specific musical sequences. Thirty-two musicians and non-musicians (19 female and 13 male) were asked to listen to a seven-chord sequence and decide as quickly as possible whether the final chord ended on the syllable /di/ or /du/. Overall, musicians were faster at the task, though non-musicians made more gains through the blocks of trials. Implicit memory for musical sequence was evident in both musicians and non-musicians. Both groups of participants reacted quicker to sequences that they had heard more than once but showed no explicit knowledge of the familiar sequences.

Keywords: Music, musician, implicit learning, implicit memory

Introduction

Musical training has been related to differences in cognitive abilities in musicians. Specifically, research has shown that music training and instrumental performance is associated with enhanced cognitive function in speech and language processing (Tierney, Krizman, Skoe, Johnston & Kraus, 2013), motor abilities (Costa-Giomi, 2005), attention and memory (Hansen, Wallentin & Vuust, 2012). Much of the research into the effects of musical training has centred on working memory, especially the function of the phonological loop and the visuo-spatial sketchpad (Hansen, Wallentin & Vuust, 2012). Working memory research has shown that musical training has positive effects at all life stages. A longitudinal study showed that children who participated in 45 minutes of weekly music lessons over an 18-month period performed better in phonological loop and central executive sub-tests compared to children who had received an equal amount of natural science training (Roden, Grube, Bongar & Kreutz, 2014). In long-term memory tasks, both verbal learning (Franklin et al., 2008) and recall tasks showed that musicians performed better than non-musicians (Talamini, Altoe, Carretti, Grassi, 2017).

There is an increased interest in the effects of musical training on implicit and explicit memory. Explicit memory is the conscious retrieval of information that has been intentionally learned (Warker & Halpern, 2005). Implicit memory is the retention of previously learned information without conscious recollection of learning it. Implicit learning is said to occur when participants improve in speed or accuracy for the previously learned information (Bergstorm, Howard & Howard, 2012). Previous research has shown that musicians perform better than non-musicians on visuo-spatial sequence learning tasks (Anaya, Pisoni & Kronenberger, 2016). However, little research has focused on implicit music learning in musicians and non-musicians. There is currently a need to devise an implicit music task that is accessible to both musicians and non-musicians enabling an insight into the effects of musical training on the processing of musical stimuli.

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This current study aimed to investigate whether an implicit musical memory task would identify any differences between musicians and non-musicians.

Implicit memory tasks use a variety of priming techniques that act on automatic processes. Priming occurs when a visual or auditory item is presented to the participant in the initial study phase of the task, which then facilitates an unconscious reaction or response to the same stimulus when presented later in the task (Ward, Berry & Shanks, 2013). Many studies, for example, use a word stem completion task to show the unconscious encoding and retrieval of words, where participants are more likely to fill in word stems with items that have been previously viewed or heard (Tulving, Schacter & Stark, 1982). Words and music have some similar characteristics. For example, they both require the use of timbral and pitch changes (Warker & Halpern, 2005; Halpern & Mullensiefen, 2008). However, due to the use of harmony, unfamiliar intervals and rhythmic groupings, music can be more complex than language which can therefore make it harder for participants to code the information in the initial study stage (Warker & Halpern, 2005).

Warker and Halpern (2005) devised a tune stem completion task that was similar in structure to commonly used word stem completion tasks. In the initial learning phase, participants were asked to listen to a set of composed melodies; some unfamiliar tunes and some that were based on known folk tunes. In the following section, selected tunes finished after a chosen note, and participants were asked to hum/sing the next note that would fit best musically. Tunes consisted of melodies heard in the previous section and novel tunes. Results showed that participants completed more tunes correctly when they had been previously heard. Warker and Halpern (2005) also devised a preference task, where they investigated different characteristics of music, such as timbre, which they postulated could help with encoding and retrieval. As in their first study, results showed that participants correctly completed more tunes they had previously heard. However, changing the characteristic of the stimuli (timbre) did not affect implicit memory or explicit memory. Peretz, Gaudreau and Bonnel (1998) presented both familiar and unfamiliar melodies to participants in

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different implicit and explicit memory tasks. In both the implicit and explicit condition there was stronger liking and recognition of the familiar melodies (Peretz et al., 1998). In contrast to the findings of Warker and Halpern (2005), timbre changes were detrimental to explicit but not implicit recall (Halpern & Mullensiefen, 2008). The result found in all of these studies shows that specific spectral characteristics of the music may be relevant to explicit learning but irrelevant for listeners' implicit memory.

While implicit memory for music can be demonstrated by using tasks that are similar to word stem completion tasks (Warker & Halpern, 2005), challenges may occur when using a musical production task as participants may feel exposed in humming or singing a response. In Warker and Halpern's study, some note productions were hard to score and data were incomplete. For this reason, tasks that do not require a vocalised response in order to demonstrate implicit learning of musical phrases may be more suitable, especially for non-musicians. The phoneme monitoring task (Bigand, et al., 2001; Tillmann, Justus & Bigand, 2008) is a musical priming paradigm used to investigate participants' implicit knowledge of tonal relations and harmonic structures. The study was focused on the prediction of harmonic relations and therefore aimed to look at harmonic priming rather than long-term memory. Bigand et al. (2001) presented an eight-chord strain that was sung using sampled synthesised vocal sounds, each chord sung to a different phoneme. Each sequence ended on either the phoneme /di/ or /du/. Participants were asked to identify as quickly as possible to which phoneme the final chord was sung. Chord sequences were split into a conventional Western cadence, which Bigand et al. called the related condition (ending on the tonic chord) and an unconventional harmonic ending, which they called the less related condition (ending on the sub-dominant chord). The target chord for each condition was never heard in the previous context. Bigand et al. (2001) found that participants were quicker to react to the harmonically related chords than the less related chords. This suggests that participants are faster to react when a familiar harmonic structure facilitates phoneme retrieval (Tillmann et al., 2008). In other words, there is less attention paid to the conventional harmonic sequence, showing implicit understanding of Western

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harmonic structures. Participants were either music graduates or students with no formal music training and the effect was found even in the absence of formal musical literacy. Using the same paradigm, implicit musical structure knowledge has also been demonstrated in cerebellar patients who have impaired sequence learning (Tillmann et al., 2008). It should be noted, however, that in both of these studies, the penultimate chord for each type of sequence was different (the dominant for the related condition and the tonic for the unrelated), which may have cued participants to predict the final chord and which may have further facilitated the phoneme recognition.

In this present study, we adapted Bigand et al.'s (2001) phoneme monitoring task to focus on both implicit knowledge of musical structure but also to study implicit memory for specific musical sequences. Both musicians and non-musicians took part to help us gain an understanding of whether musical training has impacted implicit memory and knowledge for musical structure and sequences. We have modified the task so that each sequence contains only seven chords to help the listener identify the end of the sequence which in common time represents a more commonly found rhythmic pattern ending on a strong beat. The first six phonemes were kept constant throughout all sequences and the final phoneme interchanged between the phoneme /du/ or /di/. As in Bigand et al.'s study, the harmonically related condition ended with a perfect cadence on the tonic chord. However, we adapted the less related condition so that the preceding chord was the same penultimate chord (the dominant) in both conditions. This ensured that there was no pre-cueing of the final chord. In order for participants to differentiate between the cadence and non-cadence sequences, a key must first be inferred (Bigand et al., 2001). The root position of the final/target chord was not heard previously in the sequence; however, the chord was presented as an inversion to help establish the key of the sequence. Additionally, we have added an explicit knowledge test to determine whether participants gained any explicit awareness of any sequences that they had previously heard. It was hypothesised that musicians would react quicker than non-musicians and that participants would react quicker to the phonemes attached to a conventional perfect cadence strain than the non-cadence sequences.

Method

Participants

Thirty-two young adults (19 female and 13 male) participated in the experiment: 16 musicians (seven male and nine female) and 16 non-musicians (six male and 10 female). The criteria for each group were based on previous research (Hansen et al, 2012); musicians were defined as people who were of grade 5 performance standard or above and had previously attended formal training and actively participated in music performance. Non-musicians were defined as people who did not have any musical training and were currently not involved in any music organisations. Musicians consisted of classically trained music graduates from the University of Huddersfield, the Royal Welsh College of Music and psychology undergraduate students from the University of Chester with formal musical training. Non-musicians were university graduates and students from the University of Chester. No participating non-musicians had previous individual musical training. Two participants attended a musical theatre group but were considered as non-musicians due to no formal musical training and therefore their results were not removed from the analysis. All participants were English natives and had attended English schools and therefore had only participated in music lessons according to the English National Curriculum. The National curriculum is a set of standards and subjects followed by schools around the UK to ensure all students have the same learning experience are learning the same things ("National curriculum", 2014). Music lessons involve basic listening skills and group activities, for example classroom singing and music-making. However, this may not include formally learning an instrument or musical notation. All participants were tested individually at the University of Chester or at an organised rehearsal room and gave written consent for task participation.

Table 1. Demographic information for Musicians and Non-musicians.

Characteristics	Musician	Non-musician
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Participants (N)	16	16
Male (N)	7	6
Female (N)	9	10
<hr/>		
Age (Years)		
Mean	27	24.25
SD	2	3.991
<hr/>		
Years of Musical training		
Mean	19.06	
SD	1.289	

Design and stimuli

The experiment used a mixed design, with repeated measures on harmonic relatedness, familiarity, and time of presentation, and with musician or non-musician as the grouping variable. Twenty-four different seven-chord sequences were developed using Sibelius 6 and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). Care was taken to ensure all 24 sequences were distinct and not, for example, transpositions of the same sequence. Twelve were used in an initial phoneme detection task. The other 12 were subsequently used as novel stimuli to use as controls to compare with the first 12. Each chord was sung to a homogeneous phoneme. The first six syllables of every sequence were identical (*doh, fey, so, ray, meh, to*) and were selected according to the most easily distinguishable phonemes available on VocalWriter. The final target chord was either the phoneme */di/* or */du/* (see figure 1.0). These were retained from Bigand et al. (2001) as they had found that out of the 24 consonant-vowel phonemes used in their study, they were the easiest to distinguish. The sequences were then transferred to MP3 files and the experiment was conducted using e-Prime 2.0 software. The tempo of the sequences was 92 crochet beats per minute meaning that the length of each sequence up to the onset of the target phoneme was 4005ms. There was a programming delay of 0092ms before the

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start of each sequence. The response was then timed from that onset of the seventh chord in the sequence. Participants used the computer keyboard keys 'A' for /du/ and 'L' for /di/ to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. A three second inter-stimulus-interval of white noise separated each sequence. To control for any intrinsic difficulty effects the sequences were counterbalanced across participants so that, for example, the first participant would hear Figure 1 below with the /du/ ending and the second with the /di/ending

Non-cadence sequence



Cadence sequence

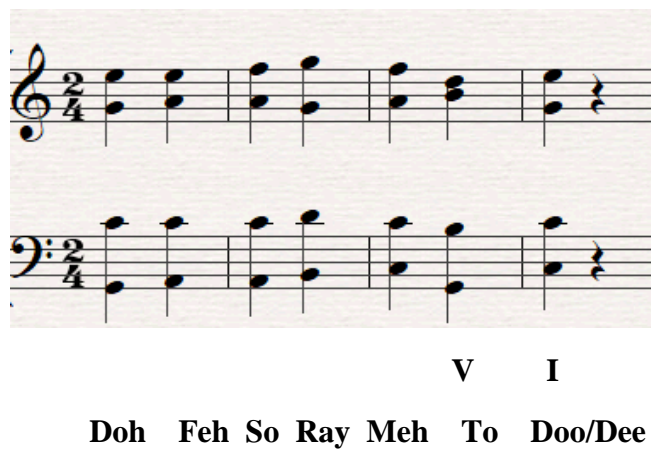


Figure 1.0 Example of cadence and non-cadence chord sequences used in the experiment.

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Procedure

Participants were asked to listen to the sequence and decide as quickly as possible whether the final chord ended on the syllable /*di*/ or /*du*/. Before the experiment began participants had three practice sequences that gave them feedback on whether they had answered correctly. The experiment was split into three blocks. The first block recorded reaction times and errors to the phoneme detection task. It consisted of 12 sequences: six cadence ending chords (three ending on the syllable *di* and three ending on *du*) and six non-cadence chords (three ending on /*du*/ and three ending on /*di*/). Three seconds of white noise was sounded after each sequence and the start of each new sequence was indicated with a beep. RT and errors to these novel stimuli were recorded. The second block consisted of 12 sequences, six sequences previously heard in block 1 (three cadence endings and three non-cadence endings), and six novel sequences (three cadence ending and three non-cadence ending). Participants were not informed that they had heard some of these sequences previously. Again, RT and errors were measured. The final block tested for explicit memory and consisted of 18 sequences (the six that had been presented in blocks 1 and 2, the six that had been novel in block 2, and the remaining six novel sequences). All were missing the final target chord. In this block participants were asked to 'guess' whether the sequence would finish either the syllable /*di*/ or /*du*/ and give a confidence rating, 1=not confident to 4=confident, of their answer. Here we assumed that if participants had explicit memory for the previously presented stimuli, they would be likely to perform at a level above chance on the previously heard sequences, but at chance on those they had not previously encountered. Within each block, all the sequences were presented in a random order that was generated by e-Prime.

Results

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A mixed measures analysis of variance was conducted comparing repeated variables (time of presentation: block one, block two; Familiarity: repeated sequences, novel sequences; Sequence ending: cadence, non-cadence), with group (musicians and non-musicians) as the between-subject variable. For each variable, an average reaction time was recorded (See table 1). Error rate was <1% and incorrect answers were not included in the averages. Reaction times were recorded from the start of the final chord (See table 1 for reaction time results).

The ANOVA showed a significant main effect of time of presentation ($F(1,30) = 31.817, p < .001, \eta p^2 = .515$). Participants reacted quicker to phonemes heard in the second block of trials compared to those heard in the first block. There was a significant main effect of relatedness (cadence and non-cadence) ($F(1,30) = 5.197, p = .030, \eta p^2 = .148$). Overall, participants responded quicker to phonemes for the chords ending on a cadence than those with the unconventional ending. A marginal effect of group ($F(1,30) = 4.014, p = .054, \eta p^2 = .118$) showed that musicians reacted quicker than non-musicians overall.

There was a significant interaction of time of presentation and group ($F(1,30) = 7.229, p = .012, \eta p^2 = .194$). Paired samples *t*-tests with an adjusted alpha level of $p < .025$ confirmed that both groups reacted quicker for chords in block 2 than block 1 (musicians $t(15) = 2.567, p = .021, d = .249$; non-musicians $t(15) = 5.090, p < .001, d = .783$). However, non-musicians showed greater improvement in reaction time for sequences heard in the second block compared to musicians. There was a significant interaction between time of presentation and familiarity ($F(1,30) = 7.382, p = .011, \eta p^2 = .197$). Post hoc *t*-tests with an adjusted alpha level of $p < .025$ showed that for unfamiliar chords, participants were faster on the second block ($t(31) = 3.546, p = .001, d = .367$; mean difference = 136 ms), suggesting an effect of practice on the task. Participants were also significantly faster on familiar chords in the second block ($t(31) = 5.606, p < .001, d = .566$), and here the larger mean difference between blocks for familiar sequences (230 ms) is suggestive of an additional effect of familiarity over and above practice effects.

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Overall, participants reacted quicker to the repeated chord sequences that had been heard in both sections compared to the novel chord sequences that were only heard once. Results showed a significant interaction of relatedness and group ($F(1,30) = 6.031, p = .020, \eta p^2 = .167$). Post hoc t -tests with adjusted alpha level of $p < .025$ showed a significant effect of sequence ending for non-musicians ($t(15) = -3.748, p = .002, d = 0.242$) who reacted quicker overall to the cadence ending than the non-cadence ending. There was no effect of relatedness for musicians ($t(15) = .094, p = .927$). No other effects were significant.

Explicit memory

In the final block, participants were asked to 'guess' what the final syllable would be. This was a forced choice answer – participants selected either /di/ or /du/ meaning that on sequences which they had heard before and for which there was a 'correct' answer, they would be expected to perform higher than chance if they had explicit memory of the sequence. A one-sample t -test was used to look at whether participants showed any explicit memory for musical sequences by comparing their responses to chance (a 50% accuracy for the choice of /di/ or /du/). This was analysed using data from the third block by looking at accuracy for chord sequences that were heard in both blocks as well as sequences that were heard in block 2 only. Familiarity on accuracy scores showed that participants were performing at chance whether they had heard the sequences twice before the final block ($M = .527, SD = .171; t(31) = .880, p = .386$) or just once before the final block ($M = .537, SD = .192; t(31) = 1.085, p = .286$).

A Pearson's correlation coefficient was also conducted and confirmed that there was no correlation between accuracy of response and confidence ratings ($r = -.75, n = 32, p = .684$).

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Table 2. Mean reaction times (ms) for familiarity (Repeated sequences, Novel sequences); Sequence ending (Cadence, non-cadence) and time (Block 1, block 2). Error rate was <1% and incorrect answers were not included in the averages.

		Familiarity					
		Repeated			Novel		
		Cadence	Non-cadence	Sub-total	Cadence	Non-cadence	Sub-total
Block 1	Musicians	981.563	963.818	972.691	971.288	953.543	962.416
		(373.934)	(384.520)	(379.227)	(349.986)	(360.572)	(355.279)
	Non-musicians	1296.422	1348.193	1322.308	1261.761	1313.532	1287.647
		(371.424)	(403.563)	(387.494)	(334.709)	(366.849)	(350.779)
	Subtotal	1138.993	1156.006	1147.500	1116.525	1133.538	1125.032
		(372.679)	(394.042)	(383.361)	(342.348)	(363.711)	(353.029)
Block 2	Musicians	853.776	869.032	861.404	875.109	890.365	882.737
		(392.879)	(440.713)	(416.796)	(372.989)	(420.823)	(396.906)
	Non-musicians	1005.583	1034.011	1019.797	1034.073	1062.801	1048.437
		(327.104)	(324.493)	(325.799)	(339.760)	(337.149)	(338.455)
	Subtotal	929.680	951.522	940.601	954.591	976.583	965.587
		(359.992)	(382.603)	(371.298)	(356.376)	(378.986)	(367.681)
Total		1034.307	1053.764		1035.558	1055.061	
		(366.336)	(388.323)		(349.362)	(371.349)	

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Table 3. Accuracy percentages for correct guesses in the explicit memory task.

	Accuracy		
	Musicians	Non-musicians	Subtotal
Block 1 and 2	52.1%	53.3%	52.7%
Block 2 only	53.8%	53.6%	53.7%

Discussion

The present experiment was designed to measure both implicit musical knowledge and to create a musical learning task to look at the implicit musical learning patterns of musicians and non-musicians. The results demonstrated that both groups showed signs of both implicit knowledge and implicit memory.

Implicit learning is observed when participants show an improvement in response to the stimuli that have been previously presented, without any explicit training on those stimuli. In this study, we used six sequences that were constant across all blocks. Results showed that both musicians and non-musicians reacted quicker to sequences that had been heard before than the sequences that were unfamiliar. Unlike Bigand et al.'s (2001) study, we found some differences in performance between musicians and non-musicians. Both groups showed an improvement in reaction times between the first block of trials, and the second block of trials, which contained some repeated material. While musicians were marginally faster at the task overall, non-musicians showed a greater improvement in reaction time between blocks. As it is unlikely that non-musicians had greater implicit learning of musical stimuli, their gains may well be attributed to practice effects. It can be concluded that participants were not guessing the phoneme ending, as we would expect the error rate to be on average of 50% if they were providing guess

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answers. As the error rate was less than 1% we can be confident that the processing time was that of real responses.

As in Bigand et al.'s (2001) study, participants were not asked to pay any explicit attention to the musical structure of the chord sequences, only the syllable of the final chord. This allowed the experiment to be used to test for harmonic priming by using modern Western cadence progressions in comparison to non-cadence chord structures. Results showed that participants reacted quicker to the cadence chord sequences compared to the non-cadence sequences. However, this varied by group; while results for non-musicians were in accordance with previous studies (Bigand et al., 2001; Tillmann et al., 2008) musicians were not affected by the structure of the cadence. A cognitive approach to harmonic priming shows that the Western harmony hierarchy of chords suggests the Western listener's internalise chords that are built on the tonic, subdominant and dominant due to mere exposure to western music and would therefore react faster to the cadence ending than the non-cadence (Bigand, Poulin, Tillmann, Madurell & D'Adamo, 2003). An alternative explanation suggests that sensory priming may be at work; a chord that shares component chords or overtones with the final chord will be anticipated and therefore should have a faster reaction time. For example, a cadence ending shares more component tones than a non-cadence ending and therefore participants will anticipate the cadence ending more than the non-cadence (Bigand et al., 2003). We are unsure why musicians were unaffected by the cadence structure, but the differences between musicians and non-musicians might be explained through the amount of musical training musicians acquire.

As well as supporting previous research which shows implicit knowledge of musical structures, we were able to demonstrate a degree of implicit memory for previously heard musical sequences. While this was confounded with more general practice effects (participants

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were faster 'across the board' in the second block of trials), the block by familiarity interaction indicates that gains made on previously heard sequences were greater than those for the novel sequences presented in the second block, with musicians performing faster overall. Our results support the findings of Conway, Pisoni and Kronenberger (2009,) which suggests that sound provides a framework, which they term the "auditory scaffolding process", which participants use to learn and process sequential auditory information. Differences in musical experience may enhance these sequencing skills. Francois and Schon (2011) supported the notion of auditory scaffolding process where they found that increased exposure to sounds benefits implicit learning.

By adapting the phoneme task, we were able to look at whether participants gained explicit knowledge from the sequences and therefore whether explicit memory affected reaction times. Explicit memory for musical sequences would be shown if participants performed above chance on those sequences that had been presented in section 2 and a further increase in accuracy for those that had been heard in both block 1 and 2. Six novel sequences that had not been heard before were used in the final section so a comparison could be made with confidence scores. As participants were not instructed to remember any information as part of the task, participants were asked to guess the ending of the sequence (whether the final syllable was /du/ or /di/) followed by giving the confidence level of their answer. As participants performed at chance (accuracy levels of c. 50%) and there was no correlation between accuracy of answers and confidence levels, we were able to conclude that participants showed no signs of explicit knowledge of musical sequences.

To conclude, we have successfully adapted Bigand et al's (2001) priming task to test both implicit musical knowledge and more temporally contiguous implicit memory for

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sequences. By generating a test of implicit musical memory that is analogous to measure of implicit verbal and visuospatial memory is the first step to discovering the extent in which musicians might be advantaged in procedural and implicit memory tasks, and whether musicianship has the ability to preserve cognitive faculties in the procedural memory domain. Repetition within musical structures is common in much popular and classical music, and our study shows that such repetition may facilitate people's listening, even when they are not explicitly aware they have encountered a specific musical phrase a few minutes earlier. This effect is found for both musicians and non-musicians; while musicians process musical stimuli faster than non-musicians, the latter seem to gain more from repetition, though future research should attempt to disengage implicit memory from more general practice effects on the task.

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